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THE AMPHIBIANS AND REPTILES OF THE ESTACIÓN BIOLÓGICA JATUN SACHA IN THE LOWLAND RAINFOREST OF AMAZONIAN ECUADOR: A 20-YEAR RECORD

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ABSTRACT. The amphibian and reptile fauna within a small area in a lowland rainforest fragment reserve in Amazonian Ecuador was intensively surveyed over an initial 2- year period via removal sampling (1986–88), coinciding with the construction of a road through the area and a subsequent surge of increased forest conversion and fragmentation in surrounding areas. A time-constrained transect sampling technique was employed to facilitate later, post-fragmentation visual-encounter monitoring to gather long-term data on species richness and composition (on a chronologically coarse scale). Between 1998 and 2005, an approximately equivalent quantity of sampling effort was accumulated in the same small area to compare with data from 1986–88, in an attempt to evaluate the efficacy of this reserve in conserving the herpetofaunal community documented more than 10 years earlier.

Based on a total of 6,722 individual records obtained over 1,117 effort-hours of sampling divided into two primary and five secondary sampling periods, herpetofaunal species richness was among the highest yet reported from a single locality in Amazonia, with 84 amphibian and 82 reptile species recorded from 1986 through 2007. A complete species list is provided, with commentary on noteworthy records. Of 73 amphibian and 46 reptile species recorded in 1986–88 sampling, 68 amphibians (93%) and 40 reptiles (87%) were recorded again in sampling from 1998 through 2007; 11 amphibian and 33 reptile species not recorded in 1986–88 were added from 1998 to 2007. Pairwise comparisons of species composition among all sampling periods using a similarity index revealed a $> 50\%$ similarity for both taxonomic groups across all periods; similarity of the two primary periods (1986–88 vs. 1998–2005) was 0.90 for amphibians and 0.70 for reptiles.

The present study provides another single-site reference point for the mega-diverse herpetofauna of the upper Amazon basin, but is distinct in offering long-term data on species persistence; results from the 20-year span of sampling suggest that this small reserve has, since 1986, successfully conserved this fauna. These results concur with previous long-term studies from the central Amazon basin in suggesting that relatively small reserves and other forest remnants with sufficient habitat diversity may substantially contribute to the continued survival of species-rich Amazon rainforest herpetofaunal communities amidst widespread regional deforestation.

KEY WORDS: Amazon; amphibians; biodiversity; conservation; Ecuador; Estación Biológica Jatun Sacha; forest fragmentation; herpetofauna; monitoring; reptiles; reserve; species richness; tropical rainforest

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Resumen. Los anfibios y reptiles que se encuentran en un área pequeña dentro de una reserva fragmentada de bosque lluvioso en la Amazonía ecuatoriana han sido intensivamente investigados en un período inicial de dos años mediante la recolección de muestras (1986–88). Esta actividad coincidió con la construcción de un camino a través del área y la subsiguiente oleada de conversión y fragmentación del bosque en las áreas circundantes. Se empleó una técnica de muestreo de transectos de tiempo restringido para facilitar luego el monitoreo de encuentro visual post-fragmentación y reunir datos de largo plazo sobre la riqueza y composición de las especies (en una escala cronológica desigual). Entre 1998 y 2005 se acumuló un esfuerzo de investigación y muestreo equivalente en la misma área reducida para compararla con la información de 1986 a 1988, en un intento por evaluar la eficiencia de esta reserva en la conservación de la fauna herpetológica documentada más de 10 años atrás.

Basada en un total de 6,722 registros individuales obtenidos durante 1,117 horas de recolección de muestras divididas en dos períodos principales y cinco períodos secundarios de muestreo, la diversidad herpetofaunística estuvo entre las más altas reportadas hasta el momento en una única ubicación en la Amazonía, con 84 especies de anfibios y 82 especies de reptiles registrados de 1986 a 2007. Se provee una lista completa de especies, con comentarios en los registros más significativos. De las 73 especies de anfibios y 46 especies de reptiles registradas de 1986 a 1988, 68 anfibios (93%) y 40 reptiles (87%) fueron registrados nuevamente en el muestreo de 1998 a 2007; 11 especies de anfibios y 33 especies de reptiles no registrados entre 1986 y 1988 fueron añadidos en 1998 a 2007. Mediante un análisis de composición de pareja entre todos los períodos de muestreo usando un índice de similitud revelaron un $> 50\%$ de similitud para ambos grupos taxonómicos entre períodos; la similitud de estos dos períodos principales (1986–88 vs. 1998–2005) fue 0.90 por anfibios y 0.70 por reptiles.

El presente estudio provee otro punto de referencia de sitio único para la herpetofauna megadiversa de la zona alta de la cuenca amazónica, pero es diferente ya que ofrece datos de largo plazo en la persistencia de especies; los resultados de un lapso de muestreo de 20 años sugieren que esta pequeña reserva, desde 1986 ha conservado exitosamente esta fauna. Estos resultados coinciden con estudios previos de largo plaza de la cuenca central de la Amazonía en sugerir que las reservas relativamente pequeñas y otros remanentes de bosque con suficiente diversidad de hábitat pueden contribuir sustancialmente a la continua supervivencia de la alta diversidad de comunidades herpetofaunísticas de los bosques lluviosos amazónicos en medio de la extendida deforestación regional.

INTRODUCTION

The rainforests of the Amazon basin harbor the highest concentration of biodiversity on Earth, yet they are being destroyed by human activities at an alarming pace; one prominent threat is deforestation and the fragmentation of previously continuous forest into smaller island remnants of remaining habitat (Bierregaard *et al.*, 2001; Lovejoy *et al.*, 1984; Myers, 1984).

Regionally, and on the basis of surveys from single localities, the lowland rainforests of the western Amazon basin of Ecuador, Peru, and Colombia are home to the highest concentration of amphibian and reptile species richness known from any area on Earth (Campbell and Lamar, 2004; Dixon and Soini, 1986; Duellman, 1999; Frost, 2007; Peters and Donoso-Barros, 1970; Peters and Orejas-Miranda, 1970). Reports on single-site studies have been reviewed by Duellman (1988, 2005) and Duellman and Thomas (1996) (also see Doan and Arizábal, 2002; Lynch, 2005). Within the immediate area of the Ecuadorian Amazon, published studies on the entire herpetofauna are available for several single or clustered sites, including Almendáriz (1987), Cisneros-Heredia (2003), Duellman (1978), Duellman and Mendelson (1995), Izquierdo *et al.* (2000), and Lescure and Gasc (1986).

From these studies, there has been an increasing awareness of the geographic and ecological heterogeneity of the Amazonian

herpetofauna, and the need to survey additional localities to better understand both local and regional distribution patterns of this mega-diverse but still poorly known fauna (Doan and Arizábal, 2002; Duellman, 2005; Lynch, 2005).

The Estación Biológica Jatun Sacha (EBJS) is a small remnant of lowland tropical wet forest located at the western edge of the Amazon Basin in eastern Ecuador, established as a reserve in 1985 shortly before the construction of a road through the area.

In 1986, coinciding with the onset of road construction, an intensive survey of the amphibian and reptile fauna was initiated. Although the first goal was to conduct a standard inventory via removal sampling, the ultimate fate of this new reserve as eventually becoming an isolated habitat island was recognized at the time, and a simple time-constrained transect sampling method was implemented to facilitate future long-term monitoring via visual-encounter surveys (VES) and to attempt to assess the long-term efficacy of the reserve in conserving the herpetofauna. A general initial prediction was that species richness would eventually decline or otherwise exhibit obvious changes in community composition.

Between 1998 and 2005, a second phase of sampling was undertaken, employing the same methods over the same small area, but with most individual records gathered via VES efforts and few collected aside from road-kill specimens. The 1986–88 and 1998–2005 periods are treated as equivalent "primary" units for comparative purposes, and each is further divided into equivalent shorter "secondary" periods on the basis of an arbitrary (and partially climate-based) division of total sampling effort (see Methods).

With the exception of Cusco Amazónico in Peru (Duellman, 1995, 2005), most previous studies from single upper Amazonian sites were conducted over relatively short spans of time (5 years or less), and within largely undisturbed expanses of continuous forest. The present paper is distinct in presenting data on the long-term composition of the herpetofaunal community within a forest fragment remnant; as such, it is offered as another single-site reference point for the upper Amazon, in the form of a traditional species checklist, and as a necessary preface to forthcoming accounts on species-level abundance and distribution derived from the same sampling efforts.

This study was undertaken several years before widespread interest in reports of amphibian declines (Blaustein, 1994; Stuart *et al.*, 2004); despite concerns over various "enigmatic" declines with causal factors ranging from epidemic disease to global climate change, the effects of habitat change are understudied and perhaps underemphasized for both amphibians and reptiles (Gardner *et al.*, 2007), especially in the Neotropical lowlands, where long-term monitoring data remain very rare (Duellman, 2005:49; Whitfield *et al.*, 2007:8355). The EBJS provides an established lowland reserve with a well-known history as a forest fragment, and is an appropriate site for monitoring the effects of habitat change on an exceptionally species-rich Neotropical herpetofauna.

METHODS

The following summary of methodology is divided into three sections, progressing from (1) a detailed description of the physical characteristics, history, and climate of the EBJS; to (2) an account of the long-term division of sampling effort and major goals within the context of this history; and to (3) the description of specific sampling protocols employed in the field as well as the scope and

deposition of specimens and records thus obtained. Online material will be available through the journal's website.

I) Description of the study site: forest, history, and climate

The EBJS is located in eastern Ecuador in Napo Province at elevations of 400 to 450 m (01°04′S, 77°37′W at main station complex; see Figs. 1–4); the reserve is owned and administered by Fundación Jatun Sacha (FJS), an Ecuadorian conservation foundation. The EBJS was the first of several reserves established by FJS and originally (1985–88) consisted of 230 ha of preserved forest owned by three independent landowners. After an initial 150-ha expansion funded by the Grateful Dead music group in 1989 (via their Rex Foundation), subsequent acquisitions of additional land have greatly increased the size of the reserve, and current total land holdings are 2,334 ha.

The EBJS forest is classified as Tropical Wet Forest (Canadas, 1983; Holdridge, 1967) and lies between the confluence of the Napo River to the north and smaller Arajuno River to the south (Figs. 1, 4). Forest within reserve boundaries consists of approximately 70% primary forest, with the remaining 30% composed of various successional stages of secondary forest growth, including approximately 95 ha of open-formation riparian habitats (Fig. 3).

Although the EBJS preserves a substantial tract of lowland rainforest, since 1985 the upper Napo region has undergone substantial changes resulting from deforestation and forest fragmentation because of increasing colonization and development. Most adjacent bordering areas have been logged or affected by agricultural activities, although no precise survey data are available. Satellite images showing general overviews of forest cover at the EBJS and in adjacent areas

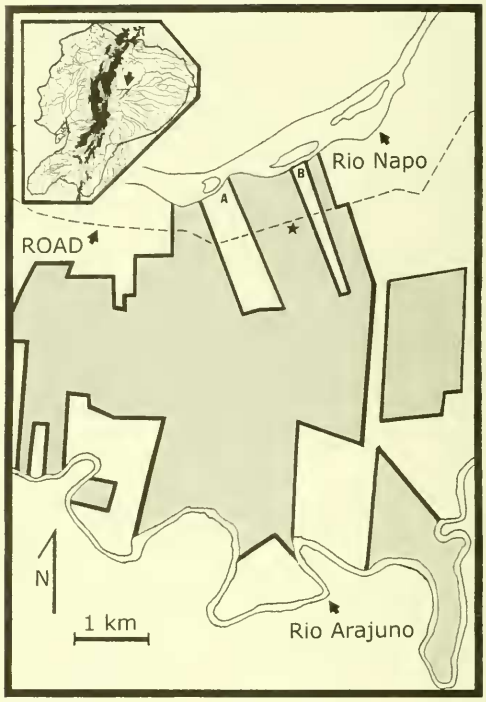

Figure 1. Current land holdings of the EBJS reserve (gray shaded areas within dark borders); location in eastern Ecuador is indicated by arrow on inset map at top left. Star indicates EBJS main station complex at approximately 01°04′S, 77°37′W. The area located between land tracts A and B comprises the Central Study Area (CSA; see Fig. 2); tract A is cleared cattle pasture, whereas tract B is a mixture of agricultural fields and various secondary forest successional stages. Also see text and Figures 3, 4. Approximately to scale.

(dating from 2000 and 2001) are presented in Figure 4 and online Figure 1.

Before the early 1980s, the region was sparsely populated and accessible only by trails or river transport, although forest conversion through small-scale logging and agricultural clearing had already affected the area for many years, especially along the banks of both major rivers. In March 1986, the construction of a road (from the west) reached the north-central area of the EBJS (Figs. 1–4), and ongoing construction now extends approximately 30 km further east.

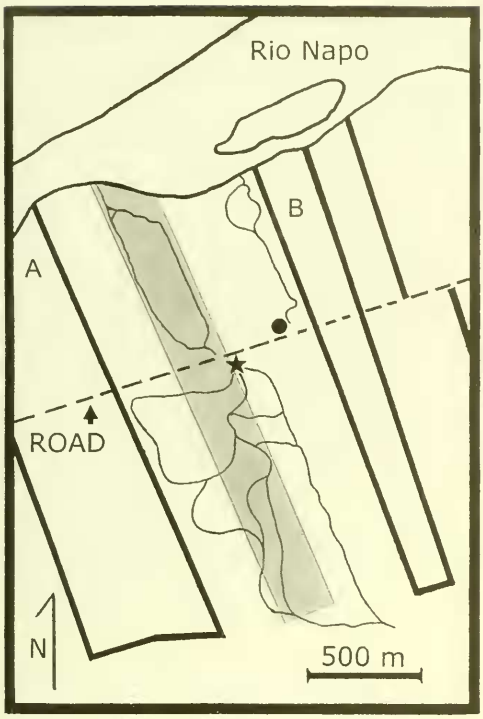

Figure 2. The Central Study Area (CSA) in the north-central region of the EBJS located between two deforested land tracts, A and B (also see Figs. 1, 4, and text). All sampling efforts as summarized in the text and online Table 1 were conducted on trail routes (irregular lines in central area) extending north and south from the EBJS main station complex (star) and north from the Librarius Study Center complex (solid circle), as well as along the margins of the road to a distance of approximately 300 m to the east and west of the main station. The gray-shaded area is shown in detail in Figure 3. Approximately to scale.

The discovery of oil reserves in the region has accelerated the process of colonization in recent years, constituting an increased threat to the EBJS reserve in the form of additional road traffic, and deforestation in nearby areas. In November 2003, a high-pressure crude oil pipeline was installed along the side of the road (buried to a depth of 2 m), and in early 2006, the road was widened by 4 m and paved with asphalt. Although the immediate area affected by the road itself within the reserve is relatively small, the larger regional effect of increased development is the predominant threat, as the EBJS has increasingly become an "island" reserve surrounded by fragmented forest.

The present study reports primarily on sampling conducted in a small (approximately 100 ha) central study area (CSA) bordering the Napo River (Figs. 1–4); the CSA includes all major habitats represented in the area (primary forest, and various river-floodplain forests, swamps, and secondary forest; Fig. 3), in contrast to land acquisitions since 1990, which have focused almost entirely on additional primary forest to the south and west. This concentration of forest types provides the most appropriate site to sample the overall amphibian and reptile diversity, in that some species occupy only limited portions of the various habitats within the EBJS as a whole.

The CSA is also the area most directly affected by the road (and forest clearing and fragmentation in adjacent areas) for the longest period of time. Two deforested tracts of land, in total area approximately equal in size to the CSA, border this area directly and entirely to both the east and west (see Figs. 1, 2, 4); both of these adjacent areas had already been partially cleared before 1986, although the largest (to the west) had undergone 10 years of secondary growth before being cleared again in 1990.

Thus, although the total area of preserved forest is today far larger by the acquisition of additional land, in keeping with the long-term goals of the study begun in 1986 (see below), subsequent sampling efforts have focused almost exclusively on this same small area.

The Ecuadorian Amazon region receives one of the highest levels of rainfall within all of lowland Amazonia. In contrast to more easterly areas, however (exhibiting pronounced wet and dry seasons), climate at

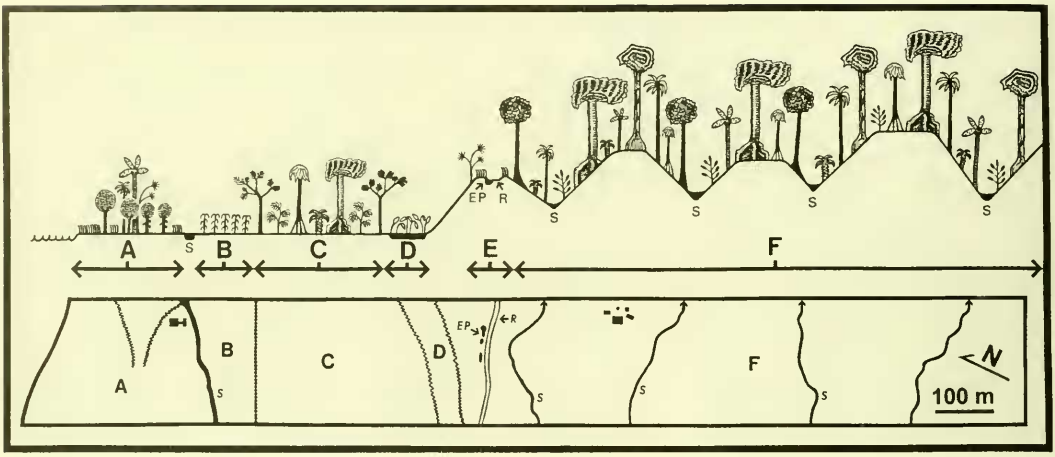

Figure 3. Map (bottom, approximately to scale), and diagrammatic cross section (top) showing relief and habitat distribution within the CSA (also see Figs. 1, 2, 4). All 1986–88 period sampling was conducted within this narrow plot and along the margins of the road to a distance of ~300 m to the east and west; approximately 70% of 1998–2005 period sampling effort was also conducted within this same small area. Areas A to D form the floodplain of the Rio Napo, area E includes the road (R) and early successional growth and ephemeral ponds (EP) along the road margins, and area F is closed-canopy primary forest on steeply rolling hills bisected by small streams (S). Within the floodplain region, area A is an ephemeral fluvial swamp surrounded by crop trees and successional growth; area B was (until 1990) cleared and planted with corn every ~6 months; area C is older secondary forest with many large trees; area D is a permanent (flowing) fluvial swamp with low *Heliconia* growth. Aside from increased secondary growth in areas A, B, and C (secondary forest in area B is now continuous with area C), this habitat distribution has remained largely unchanged since 1986.

the EBJS is far less seasonal, and rainfall can be highly irregular within any given year. The yearly distribution of rainfall is relevant to the distribution of sampling effort for the purpose of comparing faunal records between sampling periods (discussed below). Rainfall has been recorded at the EBJS since 1986, although data are incomplete for some years; for one 10-year period with complete data for each month (1994–2003; see online Table 1), total rainfall per year averaged 3,711 mm (ranging from 3,051 to 4,593 mm). This record also indicates that March–August are on average the wettest months, and September–February show the lowest average rainfall. Within any single year, however, this general pattern can vary greatly; for example, in 1996 January had the highest rainfall of any month (510 mm), and in 1997 rainfall for June and July (255 and 210 mm, respectively) was lower than both November and December (335 mm in each month).

II) Temporal distribution of sampling effort and major goals

A Coarse-Scale Sequence from "Before" to "After." Collections and records of observations of the amphibian and reptile fauna of the EBJS include two major (primary) sampling periods, each including approximately equal sampling effort, the first from 15 March 1986 to 15 February 1988 (536.0 hours total effort) and the second spanning 1 July 1998 through December 2005 (581.0 hours). Each primary sampling period is arbitrarily subdivided into secondary sampling periods (discussed below). The two primary sampling periods

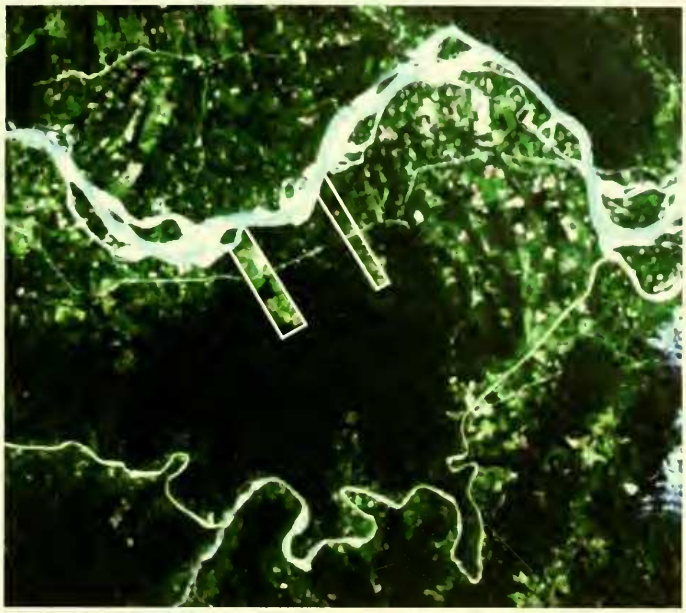

Figure 4. Landsat 7 satellite image (30 m/pixel resolution), captured 9 September 2001, showing forest cover within the EBJS reserve and closely adjacent areas. Refer to Figures 1–3 for location of major landscape features relative to reserve borders; the two outlined rectangles approximately indicate deforested areas A and B to the east and west of the CSA. Also see online Figure 1 showing forest cover over a larger area. At right, adult *Ranitomeya duellmani* (Dendrobatidae), shown 1.5× natural size.

reported here can be interpreted as "pre-fragmentation" (1986–88) and "postfragmentation" (1998–2005) data on the EBJS fauna, although as previously noted, forest conversion processes in the area had been ongoing even before 1985.

An initial program of removal sampling from 1986 to 1988 was undertaken as a baseline inventory of the fauna to facilitate subsequent monitoring of the same area in later years (1998–2005) via VES efforts, with three major goals. The first goal was to generate an initial species list (and a record of museum specimens), while employing a sampling technique that could be accurately repeated in later years.

A second goal was to accumulate equivalent amounts of sampling effort for each sampling period, with the use of results from each to monitor trends in the presence or absence (persistence) of the many species to assess the overall stability and similarity of the community over time (on a chronologically coarse scale). This is an ongoing process; hypothetically, each sampling period (and all periods combined) can provide a predictive "before" reference point to compare with subsequent equivalent sampling efforts "after," as one measure of the efficacy (or lack thereof) of the EBJS reserve in preserving the herpetofauna at this increasingly isolated site (the third major goal, with potential larger scale relevance for conservation in the region as a whole). Sorenson's quotient of similarity ($SQ = 2J[A + B]$) is used to compare the percent similarity among all sampling periods (see Results and Table 2). This simple formula estimates similarity independent of the individual abundance of each species, where A is the number of species in sample 1, B is the number in

TABLE 1. DISTRIBUTION OF NUMBERS OF AMPHIBIAN AND REPTILE SPECIES (TOP) AND INDIVIDUAL SPECIMEN RECORDS (BOTTOM) FOR ALL SAMPLING PERIODS FROM THE EBJS (ALSO SEE TEXT, APPENDIX 1, AND ONLINE TABLE 1). SPECIES TOTALS FOR THE 1998–2005 PRIMARY PERIOD INDICATE THE NUMBER OF SPECIES RECORDED, FOLLOWED BY THE NUMBER OF ADDITIONAL SPECIES (+) RECORDED LATER FROM 2006 OR 2007. FAR RIGHT COLUMN PRESENTS THE TOTAL NUMBER OF SPECIES FROM ALL SOURCES (INCLUDING "R" SPECIES) FROM 1986 THROUGH 2007, AS LISTED IN APPENDIX 1. INDIVIDUAL SPECIMEN TOTALS INDICATE THE NUMBER OF INDIVIDUALS RECORDED IN EACH PERIOD; NUMBERS IN PARENTHESES INDICATE THE INDIVIDUALS PER EFFORT-HOUR FOR EACH PERIOD.

	No. by Sampling Period							
	Total						Total	Total: All Sources
	1986–1987	1987–1988	1986–1988	1998–2001	2002–2003	2004–2005	1998–2005*	1986–2007*
Species:								
Amphibian:	63	63	73	63	54	61	78(+1)	84
Reptile:	33	39	46	34	31	55	66(+7)	82
Total:	96	102	119	98	86	116	144(+8)	166
Individuals:								
Amphibian:	1,298	1,329	2,627	1,407	989	831	3,227	5,854
	(4.87)	(4.92)	(4.90)	(6.54)	(5.47)	(4.47)	(5.55)	(5.24)
Reptile:	152	170	322	157	155	234	546	868
	(0.57)	(0.62)	(0.60)	(0.73)	(0.85)	(1.26)	(0.93)	(0.77)
Total:	1,450	1,499	2,949	1,564	1,144	1,065	3,773	6,722

*Individual totals in the 1998–2005 and 1986–2007 columns do not include records from 2006 and 2007.

sample 2, and J is the number of species common to both samples. These pairwise comparisons result in SQ values between 0 and 1, 0 indicating no similarity and 1 indicating complete similarity (SQ $\times$ 100 = % similarity).

Additional goals were to assess population fluctuations by gathering time-series abundance (and ecological distribution) data for all species individually at the EBJS. The description and evaluation of species-level patterns of abundance and distribution are, however, beyond the scope of this paper, and Table 1 presents data solely on total numbers of individuals in each major group (amphibians and reptiles) from each sampling period. Interpretation of this coarse-scale data is problematic, in that multiple variables influence abundance of the component species independently, especially among amphibians, with fluctuations in activity and apparent abundance often dependent on brief and irregular periods of high rainfall (but also see Summary and Discussion).

Although the division of sampling effort presented in online Table 1 results in two primary periods approximately equal in total effort-hours, the second primary period spanned a far longer number of years. The arbitrary division of sampling effort as shown in Table 1 and online Table 1 is a compromise that uses the available sampling effort and climate data to provide the most equivalent periods for comparative purposes.

The first primary sampling period is divided into two secondary periods (see online Table 1), providing two approximately equal units (in total effort-hours); this division also approximately corresponds to each of two annual climate periods (see below).

The second, much longer primary sampling period from 1998 to 2005 is divided into three secondary periods, varying greatly in the monthly distribution of effort-hours

TABLE 2. PAIRWISE COMPARISONS OF ALL PRIMARY AND SECONDARY SAMPLING PERIODS FROM THE EBJS FOR AMPHIBIANS AND REPTILES. THE TOTAL NUMBERS OF SPECIES FROM EACH PERIOD ARE INDICATED IN BOLDFACE IN THE COMMON CELL, AND THE NUMBERS OF SPECIES SHARED BY PERIODS ARE INDICATED AT THE UPPER RIGHT. SIMILARITY QUOTIENT (SQ) VALUES ARE INDICATED IN ITALICS AT LOWER LEFT.

Sampling Period	1986–1987	1987–1988	1998–2001	2002–2003	2004–2005	1986–1988	1998–2005
Amphibians							
1986–1987	**63**	53	53	47	51	—	59
1987–1988	*.85*	**63**	53	45	49	—	60
1998–2001	*.83*	*.83*	**64**	45	48	59	—
2002–2003	*.80*	*.77*	*.76*	**54**	51	51	—
2004–2005	*.82*	*.79*	*.77*	*.89*	**61**	57	—
1986–1988	—	—	*.86*	*.80*	*.85*	**73**	68
1998–2005	*.84*	*.85*	—	—	—	*.90*	**78**
Reptiles							
1986–1987	**33**	26	23	17	25	—	30
1987–1988	*0.72*	**39**	25	19	34	—	34
1998–2001	*0.69*	*0.68*	**34**	18	27	27	—
2002–2003	*0.53*	*0.54*	*0.55*	**31**	24	20	—
2004–2005	*0.57*	*0.72*	*0.61*	*0.56*	**55**	33	—
1986–1988	—	—	*0.67*	*0.52*	*0.65*	**46**	39
1998–2005	*0.61*	*0.65*	—	—	—	*0.70*	**66**

each year (online Table 1); this division, however, results in the most equal partitioning of the total sampling effort from the 1998–2005 period.

Relative to annual climate variation, both the 1986–88 and 1998–2005 primary periods each include in total approximately equal proportions of sampling effort expended during the wetter months (March to August) and drier months (September to February) (see online Table 1).

III) Field sampling protocol, museum and VES records, and taxonomy

Most amphibian species at the EBJS are nocturnal; some reptiles are also nocturnal, whereas others may encountered resting at night, and sampling effort was almost exclusively concentrated on searches at night, with very little total effort (24 hours; 2.1%) expended by day (these hours and records are lumped together with night sampling efforts). Thus, this study focused primarily upon the nocturnal herpetofauna (consisting mostly of amphibians) and those diurnal species of both amphibians and reptiles that typically rest at night within the areas searched.

Sampling at night consisted of carefully searching the ground and vegetation, with spotlights, along the perimeters of established trails (transects) from ground level to a height of approximately 2 m aboveground and to a distance of approximately 2 m on either side of each trail. Although the actual lengths of trail segments searched per time unit of sampling effort were generally consistent (typically on the order of approximately 300 linear meters per hour), the base unit used for comparisons between sampling periods is the person-effort-hour, defined as the hourly search effort expended by a single experienced person using the methods noted above. This was thus a form of time-constrained sampling technique (Campbell and Christman, 1982; Crump and Scott, 1994), applied to both removal and VES sampling efforts to facilitate comparisons between sampling periods. Most nightly sampling periods ranged from 2

to 5 hours in duration, and were conducted between 19:00 and 24:00.

During the first primary period (1986–88), most specimens of most species encountered were collected and preserved, with 2,810 of the total 2,949 individual records represented by museum specimens. Collecting is now restricted at the EBJS, and records from the second primary period (1998–2005) are based almost entirely on VES efforts, including a total of 3,773 individuals. With only a few exceptions (see Appendix 1 and Results), the author personally identified all specimens (from all sampling periods) via direct observation or examination of photographs (see below).

Of the total 1,117 effort-hours of sampling, 635 hours (56.8%) were conducted personally by the author, whereas the remaining 482 hours (43.2%) were conducted by persons who were trained on-site and supervised by the author, termed student collectors (SCs). Relative proportions of sampling effort by the author versus SCs were approximately equal for each primary period. Persons who assisted as SCs (and EBJS Park Guards), and their respective sampling effort contributions, are noted in the Acknowledgments.

For all sampling before August 2003, the author was present on-site with all SCs and reviewed the results of each night's sampling efforts immediately; for the 1986–88 period, and from 1998 to 2001, all specimens encountered by SCs were captured and then identified (in 1986–88, most were preserved; in 1998–2001, all were released within 48 hours).

Beginning in March 2002, the physical capture of specimens by SCs was discontinued and digital cameras were used to photograph every amphibian and reptile specimen encountered; all other aspects of sampling methods remained the same, and identifications were determined solely from photos.

From August 2003–December of 2005, a large portion of the total sampling effort (231.5 hours) was conducted by Park Guards employed by the EBJS. In a project funded by the Declining Amphibian Populations Task Force (DAPTF), park guards were trained on-site in search techniques and the use of digital cameras. Park Guards then continued periodic sampling in the author's absence, and images of all individuals encountered were saved on compact disc (CD) for later review and identification (1,065 identified individuals).

Although most of the 6,722 individuals from all sampling periods were recorded during regularly measured sampling efforts, a total of 376 records (5.6%) represent individuals that were randomly encountered outside the 1,117 hours summarized in online Table 1. Appendix 1 also includes all species known to the author from the EBJS since 1986 from all sources, including additional records from 2006 and 2007, and a few important records from other investigators (see Appendix 1, Table 1, and Results).

The majority (75%) of specimens collected during the 1986–88 removal sampling effort are deposited in the herpetological collections of the Museum of Comparative Zoology at Harvard University (MCZ); the remainder are housed in other collections (primarily in Ecuador). The following list of additional museum collections is presented in approximate decreasing order of the total number of included specimens at each museum (with acronyms): Museo Ecuatoriano de Ciencias Naturales, Quito (MECN); Museo de Zoología, Pontifica Universidad Catolica del Ecuador, Quito (QCAZ); American Museum of Natural History (AMNH); Florida Museum of Natural History (UF); United States National Museum (USNM); University of Kansas Museum of Natural History (KU). All specimens collected from 1998 to 2007 are deposited at the QCAZ (all

referenced by the author's "GV" field numbers in species accounts below). Duplicate copies of the photographic record from 2003 to 2005 (with identifications and full data) are deposited at MCZ, MECN, and QCAZ and with the DAPTF. Online Appendix 1 presents a complete list of all museum specimens; full data for MCZ specimens can be accessed on-line at www.mcz.harvard.edu.

Since studies were initiated in 1986, the nomenclature for more than 70% of species of amphibians (and some reptiles) known from the EBJS has been revised; for some species, both generic and family assignments have changed as a result of numerous recent phylogenetic investigations (see Frost, 2007). The present paper uses the most current published taxonomy, following the frequently updated online references of the QCAZ of Coloma (2005–2007) for amphibians (which largely follows Frost, 2007), and Coloma *et al.* (2000–2007) and Torres-Carvajal (2000–2007) for reptiles (excepting Iguanidae). These nomenclatural changes are likely to remain the subject of future debate (Frost, 2007; Wiens, 2007, 2008); adoption of the most recently proposed binomials as employed here is not necessarily intended as an endorsement of any of these arrangements, as much as an attempt to best present the most current and complete historical sequence of taxonomic opinion.

RESULTS

Appendix 1 lists all species reported from the EBJS by all sources from 1986 to 2007, indicating the presence or absence of records in each sampling period; Table 1 summarizes data on numbers of species and individual records for all sampling periods.

In total, 84 species of amphibians and 82 species of reptiles have been recorded from the EBJS since March 1986. Total amphibian species include 79 anurans, 2 salamanders, and 3 caecilians, whereas reptiles include 4 chelonians, 2 crocodilians, 1 amphisbaenian, 21 lizards, and 54 snakes.

During the first primary period (1986–88), a total of 73 species of amphibians and 46 reptiles were recorded, whereas the second primary period (1998–2005) included a total of 78 species of amphibians and 66 reptiles. These totals, and comparisons of sampling period totals presented below, all exclude three species included in Appendix 1 on the basis solely of reports by EBJS staff ("R" species; see Appendix 1).

Of 73 species of amphibians recorded in 1986–88, only five (6.8%) were not recorded again from 1998 to 2007 (*Hylomantis hulli*, *Hypsiboas geographicus*, *Nyctimantis rugiceps*, *Edalorhina perezi*, and *Strabomantis sulcatus*), and 11 species that were not recorded in 1986–88 were added between 1998 and 2007 (see Appendix 1).

Of 46 reptiles recorded in 1986–88, six species (13.0%) were not recorded again in 1998–2007 (*Chelonoidis denticulata*, *Anolis nitens scypheus*, *Mabuya nigropunctata*, *Uracentron flaviceps*, *Liophis reginae semilineata*, and *Ninia hudsoni*); 33 reptile species were added in 1998–2007. Of the latter 33, three species (*Anolis transversalis*, *Polychrus liogaster*, and *Corallus caninus*) were recorded by other investigators in 1989 but are treated as new additions relative to the 1986–88 sampling efforts (see Appendix 1, and species accounts below).

In total, 93.2% of amphibian and 87.0% of reptile species recorded at the EBJS in initial 1986–88 sampling were recorded at some point again between 1998 and 2007.

One crude measure of similarity among sampling periods is the total number of species recorded in each period relative to the quantity of sampling effort, which can be expressed as simply the number of species per effort-hour (SPH). Total SPH continu-

ally decreases with increasing sampling effort as species accumulation approaches an asymptote; relevant comparisons can be made between the approximately equivalent five secondary and two primary periods. SPH values noted below exclude species recorded solely from 2006–07 (see Appendix 1 and Table 1).

SPH values for amphibians for secondary periods are 0.24 (1986–87), 0.23 (1987–88), 0.30 (1998–2001), 0.30 (2002–03), and 0.33 (2004–05). Amphibian SPH for the 1986–88 primary period was 0.14, and 0.13 for the 1998–2005 primary period. SPH values for reptiles are 0.12 (1986–87), 0.14 (1987–88), 0.16 (1998–2001), 0.17 (2002–03), and 0.29 (2004–05) for secondary periods and 0.08 (1986–88) and 0.13 (1998–2005) for the two primary periods. These data, while crude, indicate that SPH exhibited no obvious decreasing trend for amphibians (with values for both primary periods nearly equal), whereas reptile SPH values suggest an increasing trend over all comparable sampling periods between 1986 and 2005.

Table 2 presents pairwise comparisons of all sampling periods using Sorenson's similarity quotient (SQ; see Methods), including the similarity of both primary periods to all secondary periods. Primary versus secondary periods, however, are not directly comparable, in that total sampling effort for each primary period is far greater than total effort for each secondary period. Similarity in the long-term persistence of species richness and composition is a central focus, and thus the chronologically most widely spaced periods are of special interest. Comparisons of similarity in species composition in Table 2 exclude records from 2006 and 2007 (Appendix 1 and Table 1).

For amphibians, SQ values indicate a high percent similarity among all sampling periods, ranging from 0.76 to 0.90. Similarity of each of the first two secondary periods to all three later equivalent periods ranges from 0.77 to 0.83. The amphibian species SQ for the two primary periods in total is 0.90. Together, these values suggest a robust persistence in overall species composition of the EBJS amphibian community over an almost 20-year span of sampling.

For reptiles, SQ values are lower and more variable than for amphibians, ranging from 0.53 to 0.72 for equivalent periods. Reptile SQ for the two primary periods is 0.70, despite an almost equal total number of species; however, as summarized in Table 1, apparent abundance of reptiles as a group is far lower overall than for amphibians, with most species (especially snakes; $>$ 65% of total reptile species) represented by far fewer individual and sampling-period records.

The 0.70 similarity of the two primary periods nevertheless suggests a strong overall persistence in reptile species composition given that the majority of these persistent species were commonly encountered in regular night sampling (whereas many others were known only from random encounters), and 27 of 66 species recorded in the 1998–2005 period (excluding 2006 and 2007 records) were not recorded in the first primary period.

SELECTED SPECIES ACCOUNTS

Having summarized data on species composition over all sampling periods, it is appropriate to review some especially noteworthy species records. These include species described on the basis of type material collected at the EBJS, species not yet described when first recorded from the EBJS but later described on the basis of material collected elsewhere, and records that possibly represent undescribed species or for which identification is uncertain. Also noted are contributions from other investigators and

informants, including published studies on various species conducted at the EBJS, and a number of range extensions. Full names of contributors (with abbreviations) are presented initially, with abbreviations alone used for any subsequent citations. For some accounts in which taxonomic history is noted, older generic names are used, with current names (as listed in Appendix 1) indicated in parentheses. The following accounts are presented in the same taxonomic order as in Appendix 1.

Amphibians

Anura: Bufonidae

Rhinella "margaritifera" (Laurenti)

Previously widely known under the specific epithet "*typhonius*," toads currently grouped under the name "*margaritifera*" include multiple cryptic species (as many as a dozen or more) distributed throughout the lowland Amazon basin (Fouquet *et al.*, 2007; Hass *et al.*, 1995). Duellman and Mendelson (1995) described and illustrated three forms from Loreto, Peru; among preserved adults available from the EBJS (from 1986–88), apparently at least two very similar forms are represented.

Anura: Dendrobatidae

Allobates zaparo (Silverstone), *Ameerega bilinguis* (Jungfer), and *Ameerega parvula* (Boulenger)

Collections of these three similar species were conducted at the EBJS and nearby areas from 2003 to 2005 by Catherine R. Darst (C.R.D.) pursuant to studies concerning diet, toxicity, and the evolution of aposematic coloration and predator avoidance among these and other dendrobatids (Darst *et al.*, 2005, 2006; Darst and Cummings, 2006). As a result of these efforts, the distribution patterns of all three species at the EBJS are now better understood; *A. zaparo* and *A. bilinguis* co-occur extensively in primary forest within the CSA, whereas *A. parvula* apparently occurs only in primary forest areas to the south (C.R.D., personal communication).

Hyloxalus sauli (Edwards)

This species is included on the basis of a report by Morley Read (M.R.) of males heard calling within the CSA in January 2005; he has extensively documented the vocalizations of Amazonian anurans and is familiar with this species at other localities (see Read, 2000). In addition, two individuals collected in the 1987–88 period were tentatively identified as *H. sauli* (and are included as such in Appendix 1); these specimens were however apparently misplaced and never cataloged into the MCZ collections, and their identity could not be confirmed.

Among *Hyloxalus* species known from Amazonian Ecuador, two additional species (*H. bocagei* and *H. shuar*) could be expected at the EBJS on the basis of their known distributions (Coloma, 1995, 2005–2007). The paucity of *Hyloxalus* records is puzzling given the presence of presumed ideal habitat at the EBJS; although unidentified juveniles have occasionally been encountered while active by day (most from areas to the south of the CSA), adults have remained remarkably elusive, and no records of *Hyloxalus* have been obtained in night sampling.

Anura: Hylidae

Cruziohyla craspedopus (Funkhouser)

This species was initially recorded by M.R. from a single adult photographed near the EBJS main station in April 1998. A second adult was found by Paul S. Hamilton (P.S.H.) in June 2007, and a third by M.R.

in August 2007 (none collected, and all within the CSA).

Hylomantis hulli (Duellman and Mendelson)

Three specimens (MCZ A 111179–180, 118541; see online Fig. 2) collected in 1987 were initially identified as *Phyllomedusa* (*Hylomantis*) *buckleyi*, a similar species known from the eastern Andean slopes in Ecuador from 400 to 1,870 m elevation (Cannatella, 1980). Following the description of *Phyllomedusa* (*Hylomantis*) *hulli* by Duellman and Mendelson (1995), all three EBJS specimens were re-examined and found to conform to *H. hulli*, all exhibiting the diagnostic coarsely granular dorsal skin with heel calcars absent (skin finely granular and prominent calcars present, in *H. buckleyi*). These specimens apparently represent both the westernmost locality, and highest elevational records (approximately 420 m) yet reported for this species.

Hypsiboas cinerascens (Boulenger)

In January 2005, M.R. reported multiple males of *Hypisiboas cinerascens* calling from a swamp area near the Río Napo (within the CSA); this is the only known EBJS record.

Osteocephalus cabrerai (Cochran and Goin)

A large series of specimens collected in the 1986–88 period were initially identified as *Osteocephalus buckleyi* (see MCZ online catalog and online Appendix 1); *Hyla* (*Osteocephalus*) *cabrerai* was described by Cochran and Goin (1970:215) but then was relegated to the synonomy of *O. buckleyi* by Trueb and Duellman (1971). Duellman and Mendelson (1995) removed *O. cabrerai* from the synonomy of *O. buckleyi* on the basis of a single specimen collected in Loreto, Peru, and provided color photos of the Loreto specimen of *O. cabrerai* and another of an *O. buckleyi* from the same region. On the basis of numerous photos of living specimens from the EBJS, as well as examination of specimens in the MCZ, all represent *O. cabrerai*. Because these were not directly compared with other specimens of either species and the two are morphologically very similar, the entire series at the MCZ remains cataloged as *O. buckleyi*.

Osteocephalus deridens (Jungfer, *et al.*) and *Osteocephalus fuscifacies* (Jungfer, *et al.*)

Although *Osteocephalus deridens* and *O. fuscifacies* were collected in the 1986–88 period, both were initially confused under the name *O. leprieurii*. Following descriptions by Jungfer *et al.* (2000) on the basis of holotypes collected at the EBJS, the specimens from the 1986–88 period were reexamined, revealing one adult male of each species (*O. deridens*: MCZ A 111191; *O. fuscifacies*: MCZ A 111189). A call tape of the *O. deridens* was also recorded postcapture in 1988, further confirming its identity (online Audio File 1 and online Fig. 3).

Osteocephalus deridens is represented by multiple records since 2001, but the single *O. fuscifacies* from 1987 remains the only record obtained in this study; the *O. fuscifacies* record in Appendix 1 includes only the holotype collected in 1997 (Jungfer *et al.*, 2000).

Phyllomedusa coelestis (Cope)

This species (online Fig. 4) is known from only two records at the EBJS (both adults, not collected), the first found by M.R. in January 2005, and the second by the author in October 2005; both records were from primary forest within the CSA. All diagnostic characters of the latter fully conform to the redescription and illustration provided by Duellman and Mendelson (1995). These

apparently represent only the second and third records known from Ecuador, extending the range approximately 200 km west from Yasuní, and are the highest elevational records for this species (420 m).

Scinax fuscus (Cope)

Although *Scinax fuscus* was not initially recorded in this study until July 2003, Duellman and Wiens (1993) reported a single specimen from the EBJS collected by Luis Coloma in May 1990.

Anura: Microhylidae
Microhylidae *incerta sedis*

This species is included on the basis of a single specimen (QCAZ: GV2000-0329) collected by day in June 2001 on the south side of the EBJS in primary forest near the Río Arajuno. Although resembling *Chiasmocleis ventrimaculata* in dorsal and ventral coloration, at 32.0 mm snout-vent length (SVL), it is much larger (SVL 20–24 mm in *C. ventrimaculata*) and apparently conforms to no species yet reported from Amazonian Ecuador. The dorsum was dull grayish-brown (body and limbs) with a thin pale middorsal line, the venter (throat, body, and limbs) mottled cream and pale brown; skin smooth (dorsally and ventrally), dorsal occipital fold absent; fingers and toes lacking webbing; tympanum and annulus not evident; eyes very small, iris brown.

Anura: Strabomantidae
Pristimantis aureolineatus
(Guayasamín *et al.*)

The first record of *P. aureolineatus* from the EBJS is a single adult (MCZ A 109239) collected in May 1986 and initially identified as *Eleutherodactylus* (*Pristimantis*) *lacrimosus*, with two additional individuals (not collected) recorded in the 1998–2005 sampling period. Following description by Guayasamín *et al.* (2006), in which *P. aureolineatus* was assigned to the *lacrimosus* assemblage on the basis of type material from widely scattered localities in northeastern Ecuador and Peru, the three EBJS records were recognized as conforming to *P. aureolineatus*. These apparently represent both the westernmost locality and the highest elevational records (approximately 400–425 m) yet reported for this species.

Pristimantis librarius (Flores and Vigle)

Flores and Vigle (1994) described *Eleutherodactylus* (*Pristimantis*) *librarius* on the basis of a series of 40 specimens, all collected at the EBJS during the initial 1986–88 sampling period. This species was apparently known only from the EBJS until Elmer (2004) reported *P. librarius* from several localities throughout lowland eastern Ecuador.

Pristimantis ockendeni (Boulenger)

Kathryn R. Elmer made extensive collections of *Eleutherodactylus* (*Pristimantis*) *ockendeni* at the EBJS and throughout eastern Ecuador from 2003 to 2005 pursuant to studies on population genetic structure and diversity (Elmer *et al.*, 2006, 2007a, 2007b). As a result of these studies, Elmer and Cannatella (2008) recently identified and described three cryptic species in eastern Ecuador (*Pristimantis achuar*, *P. altamnis*, and *P. kichwarum*), all of which had previously been confused under the name *E. ockendeni*; they further speculate that *Eleutherodactylus* (*Pristimantis*) *ockendeni* (*sensu stricto*) is most likely a name that has been misapplied to Ecuadorian populations for many years and suggest that this species probably does not occur in Ecuador.

Among these three new species, both *P. altamnis* and *P. kichwarum* are reported from the EBJS. Presumably, records reported here include specimens of both new species (among material collected in 1986–88, as well as VES records from 1998 to 2005), although none of the many existing specimens (or photographic records) have yet been examined by the author (or Elmer and Cannatella, 2008) in comparison to these very recent descriptions, and all are thus included here under the single prior name "*ockendeni*."

Pristimantis species I

Pristimantis sp. I was initially recorded in the 1986–88 sampling period on the basis of a 32.0-mm SVL gravid adult female (MCZ A 129304; online Fig. 5) and seven adult males ranging from 20.0 to 22.0 mm SVL. Although uncommon at the EBJS, additional records were obtained between 1998 and 2005. Aside from its larger size, in both morphology and color *Pristimantis* sp. I is remarkably similar to *P. martiae* (males 13.2–16.8 mm SVL, females 18.3–23.0 mm SVL; Lynch, 1974), a far more common species at the EBJS. Both species share a range of characters, including the lack of an external tympanum (although a partial tympanic annulus is faintly evident in some specimens of both species), similar snout shape, skin texture, dark supratympanic and canthal stripes, and a bronze iris with a broad dark-reddish horizontal median streak. Remarkably, both also share the same polymorphic dorsal coloration, with two discrete morphs exhibited in both species. In both species, some individuals of both sexes are pale brown to gray dorsally with 3 or 4 darker chevron-shaped transverse bands, whereas others have a lineate pattern of longitudinal pale to dark brown stripes of varying widths from the tip of the snout to the vent. Lynch (1974) noted a 3:1 ratio in chevron:lineate morphs among specimens of *P. martiae* cited in the original description; at the EBJS, a nearly identical ratio was evident among 61 *P. martiae* collected in 1986–88. For *Pristimantis* sp. I, the lineate morph was more common, in an approximately opposite proportion.

Duellman and Mendelson (1995) described *Eleutherodactylus* (*Pristimantis*) *delius* from Loreto, Peru (approximately 210 km SE of the EBJS) on the basis of a single adult female. This species bears a close resemblance to *Pristimantis* sp. I, sharing a nearly identical dorsal pattern of pale and darker brown stripes, and dark supratympanic and canthal stripes; at 30.9 mm SVL, the holotype of *P. delius* also falls precisely within the observed size range for adult female *Pristimantis* sp. I at the EBJS. The two differ however in that *P. delius* exhibits a distinct tympanic membrane and annulus and lacks vomerine odontophores (tympanic membrane not evident, but with faintly evident annulus, and vomerine odontophores present in all preserved specimens of *Pristimantis* sp. I). Despite these differences, *Pristimantis* sp. I might be conspecific with *P. delius*; specimens from the EBJS have not yet been compared with the holotype of *P. delius*, and final determination must await direct comparisons.

Pristimantis species II

This species is included on the basis of a single individual (sex undetermined) found, but not collected, within the CSA in June 1999 (online Fig. 6). Because this individual cannot be referred to any described species, a brief description is provided.

SVL 21.5 mm; limbs short and robust in proportion to body, hands and feet lack webbing, first finger shorter than second, finger and toe pads expanded and rounded. Prominent supratympanic fold present, but

tympanic membrane and annulus not evident. Snout rounded dorsally and in profile. Skin of entire dorsum (head, body, and limbs) thick and glandular in appearance, covered with low, rounded tubercles; tubercles coalesce dorsolaterally to form faintly evident, broken dorsolateral ridges. Entire dorsum uniform grayish-brown at night, but dark brown (almost black) by day, with widely scattered metallic-gold flecks 0.5–2.0 mm in diameter (most obvious under magnification); faintly evident darker transverse bands dorsally on arms and legs. Entire venter brown except for pale gray groin area with a bluish tinge; anterior, posterior, and other concealed surfaces of legs unmarked pale gray. Iris silver with fine black reticulations dorsally, denser black reticulations ventrally, a broad rusty-red median stripe, and a very narrow red pupil ring.

Caudata: Plethodontidae
Bolitoglossa equatoriana (Brame and Wake) and *Bolitoglossa peruviana* (Boulenger)

Cisneros-Heredia (2006) reported several new geographic records for *B. equatoriana* and cited one specimen collected at the EBJS in 1999 as representing the southernmost record for this species, which is known only from east-central Ecuador; the EBJS is apparently also the easternmost and highest elevation locality.

Both *B. equatoriana* and *B. peruviana* were among the most ubiquitous and abundant amphibians in all forest habitats at the EBJS throughout all sampling periods, each represented by more than 300 individual records since 1986.

Gymnophiona: Caeciliidae
Caeciliidae *incerta sedis*

This species is included on the basis of a single individual found at night on a primary forest trail within the CSA in June 1999. Because this individual (not collected) was clearly distinct from the other two species known from the EBJS, but could not be identified by direct examination of the specimen in the field, a brief description follows (also see online Fig. 7).

Total length approximately 360 mm; midbody diameter 11–12 mm; dorsum deep blue fading to paler blue ventrolaterally; midventrally also deep blue, slightly darker than dorsum. Head elongate, tentacles thin and white to cream; eyes not evident externally aside from very small pin-point dermal depressions. Number of costal grooves approximately 110.

Reptiles
Chelonia: Chelidae
Mesoclemmys gibba (Schweigger)

DeForce *et al.* (2004) conducted mark-recapture studies on *Mesoclemmys gibba* at a small pond within the CSA in 2001 but were unable to estimate population size because of extreme "trap-happy" behavior.

Chelonia: Podocnemididae
Podocnemis unifilis (Troschel)

This species is included on the basis of a photograph of several adults basking on a log in the Río Arajuno on the south side of the EBJS (taken by a visitor; date unknown). The presence of *P. unifilis* along the Río Arajuno bordering the EBJS is also presumed on the basis of observations of this species from the Río Arajuno near its confluence with the Río Napo.

Crocodylia: Crocodylidae
Caiman c. crocodilus (Linnaeus)

EBJS Founder and Director, G. Alejandro Suárez (G.A.S.) observed what was appar-

ently an adult *C. crocodilus* in a fluvial swamp on the floodplain of the Río Napo (within the CSA) in 1990. No additional reports are known from the EBJS; however, some might survive in more remote areas of the Río Arajuno on the south side of the reserve.

Sauria: Iguanidae
Anolis transversalis (Dumeril) and *Polychrus liogaster* (Boulenger)

Both *A. transversalis* and *P. liogaster* were initially recorded by Laurie J. Vitt (personal communication) in May 1989; identification (via photos) of the *P. liogaster* was later determined by William W. Lamar (W.W.L.). Although excluded from 1986–88 sampling period totals, both species were recorded again in the 1998–2005 period (and in 2006). The former was recorded in June 2005 (by P.S.H.) and August 2006 by Alexis Harrison (one adult each), and the latter from July 2003 and September 2006 (also one adult each; the 2003 record is shown in online Fig. 8).

The single *P. liogaster* from 2006 was a road kill (QCAZ: GV2000-0349) collected by EBJS Park Guard Milton G. Orozco (M.G.O); this and previous EBJS records apparently represent the first reports from Ecuador, and a very substantial range extension for this species, extending the range approximately 1,000 km to the NW from the nearest reported records in western Brazil (see Avila-Pires, 1995:131, 134).

Serpentes: Boidae
Corallus caninus (Linneaus)

The first record was an adult photographed by M.R. in 1989 (date unknown; not collected); two additional adults were recorded in 2006 (all were found within the CSA).

Serpentes: Colubridae
Atractus species

Among material collected in 1986–88 (as well as additional VES records since 1998) are specimens of a small *Atractus*, which in diagnostic characters of lepidosis conform to *Atractus major* (MCZ R 173868-871; online Fig. 9); however, these form a series consistently varying from all other EBJS specimens referred to *A. major* and are here treated tentatively as a possibly distinct cryptic species pending the collection and evaluation of additional specimens.

All individuals of *Atractus* sp. have a dorsal pattern of alternating short and long dark red bands, with each band separated by a shorter black band; the short red bands are paler and brighter in shade than the long bands, and all bands extend unbroken laterally across the dorsum. In contrast, all *A. major* exhibit a dull brown dorsal ground color with short dark brown bands and irregular markings (with short pale tan outlines) that are broken middorsally with few (if any) bands laterally continuous across the dorsum. Morphologically, there is a striking difference in the size of the eye; the eyes of *Atractus* sp. are distinctly smaller relative to head size than are those of *A. major*. These differences are obvious if specimens are compared directly.

Additional Notes on Colubridae

Several colubrid species and period records are included in Appendix 1 on the basis of reports or identifications by other investigators, but otherwise require no further commentary.

Records from 1998 to 2005 of *Dipsas pavonina*, *Drepanoides anomalus*, and *Oxyrhopus formosus* were obtained by Park Guards Willan G. Poveda and M.G.O.; identifications (from photos) for all of these were kindly determined by W.W.L.

Pseustes s. sulphureus is included on the basis of a photograph taken by Karl-Heinz Jungfer in December 1997 and subsequently identified by W.W.L.

Initial records and identifications for *Drymobius rhombifer*, *Oxyrhopus petola digitalis*, and *Siphlophis cervinus* were reported by Dale F. DeNardo (D.F.D.), Martin J. Fouquette, and P.S.H. from June 2005. They also reported all 2004–05 period records for *Atractus occipitoalbus*, *Chironius exoletus*, *Oxyrhopus melanogenys*, *Siphlophis compressus*, and *Umbrivaga pygmaea* (from June 2005), and D.F.D. reported *Oxybelis fulgidus* from June 2007.

Serpentes: Viperidae
Lachesis muta (Linnaeus)

Both G.A.S. and Park Guard Gabriel Tapuy (G.T.) have observed *L. muta* within the general upper Napo area, and G.A.S observed at least one within the CSA. A large skin owned by G.T. came from an individual collected in the area, although the exact locality is unknown.

SUMMARY AND DISCUSSION

In many respects, the EBJS forms a microcosm relevant to a number of important issues pertaining to Amazon rainforest conservation, including questions concerning the appropriate minimum reserve size required to identify and conserve viable biotic communities, the long-term effects of continuing development and fragmentation on surviving habitat islands, and the need to inventory and monitor all component organisms to address these questions (Bierregaard *et al.*, 1997, 2001; Laurance *et al.*, 1997; Lewin, 1984; Simberloff and Abele, 1982; Turner, 1996; Turner and Corlett, 1996).

The need to first inventory and later monitor is essential to determine what is being preserved and to assess the persistence of the community under study; the success of any conservation effort is best measured by documenting community persistence (and fluctuations) over long periods of time (Blaustein *et al.*, 1994; Teder *et al.*, 2007). Unfortunately, poorly known, yet species-rich, rainforest ecosystems require ongoing sampling effort combined with taxonomic expertise; a shortage of human and material resources often renders such efforts difficult and limited in scope (Bierregaard *et al.*, 1997; Crump, 2003).

The techniques employed in this study utilized minimal resources, including one principal investigator (the author), persons who were trained in field sampling methods (SCs and EBJS Park Guards), and (most recently) the use of new imaging technology (digital cameras) combined to gather simple long-term data on the persistence of species richness and composition. Although studies evaluating sampling methods for monitoring tropical herpetofaunas have recently been undertaken (Doan, 2003; Funk *et al.*, 2003), whatever method is employed must be both consistent and sustainable over time if an accurate assessment of the community is to be attained (Teder *et al.*, 2007).

Assuming that the methods employed in this study gathered accurate data on long-term species persistence as a measure of conservation efficacy, results reported here suggest that the EBJS has, since 1986, very successfully conserved the resident herpetofaunal community. After almost 10 years of isolation in an increasingly fragmented area, monitoring over the subsequent 10 years (1998–2007) revealed that 92% of amphibian and reptile species initially recorded in 1986–88 were also present at some point later during 1998–2007. The number of species added in 1998–2007 for both amphibians (11) and reptiles (33) far exceeds the number of 1986–88 species lacking subsequent rec-

ords from 1998–2007 (thus there were very few possible "ghosts"; see Dayton *et al.*, 1998). The increase in reptile species records for the 2004–05 period in particular is partially attributed to a combination of (1) increased vehicular traffic and increased effort in collecting the resulting road-kill specimens, (2) the use of digital cameras to document randomly encountered individuals, and (3) contributions from other investigators. New species records for both groups continue to accumulate; snakes now predominate, although a large amphibian (*Rhaebo glaberrimus*) was added within the CSA as recently as June 2007.

Pairwise comparisons for amphibians among equivalent sampling periods (far better sampled than reptiles, in total records represented) all reveal a high percent similarity in species composition (from 0.77 to 0.90), whereas similarity for reptiles is lower but exceeds 0.50 for all equivalent pairs, and is 0.70 for the two primary periods. Crude measures of both species (SPH) and individuals per sampling effort-hour for both major groups vary among sampling periods, but none suggest any pronounced declines. Interpretation of group-level abundance data is problematic; given the large sample sizes represented, however, lumped data on even this coarse scale provides baselines (and ranges of variation) that could be used to predict and monitor expected long-term patterns of abundance at the EBJS over future equivalent sampling periods.

Perhaps the most remarkable result is not merely the robust persistence of the community, but the concentration of 161 species recorded from the CSA within a sampled area of only 100 ha directly bordering two large tracts of deforested land (Figs 1–4). More than 80% of total sampling effort was conducted along precisely the same trails within the CSA over the entire 20-year span of sampling. Most of the interior regions of the reserve remain almost entirely unstudied; additional species may be expected from these areas.

Including all records to date, the herpetofaunal species richness of the EBJS is already among the highest ever recorded for any single Neotropical site. For amphibians, only Tiputini and Santa Cecilia (both located in Ecuador to the NE of the EBJS; Cisneros-Heredia, 2003; Duellman, 1978) and forests to the north of Leticia, Colombia (Lynch, 2005) have recorded more amphibian species (also see Doan and Arizabal, 2002; Duellman, 2005; Duellman and Thomas, 1996). Santa Cecilia has been completely deforested for many years as a result of colonization and oil extraction, leaving the EBJS second only to Leticia and Tiputini in amphibian species richness among currently extant sites. Reptile species richness at the EBJS is greater than reported for Tiputini (Cisneros-Heredia, 2003) and is exceeded only by Santa Cecilia within the upper Amazon region (Duellman, 1978) and Cusco Amazónico and Explorers Inn in the Tambopata region of southeastern Peru (Doan and Arizabal, 2002; Duellman, 2005).

Only a few studies have addressed the long-term effects of forest fragmentation on anuran amphibians in lowland Amazon rainforest (none from the more species rich upper Amazon). Tocher *et al.* (1997) examined pre- and post-isolation species richness among small (1–100 ha) fragments of primary forest over a 10-year period in north-central Brazil (40 species). Contrary to their initial predictions, few species were lost from fragments following isolation, and fragments of all sizes showed increases in species richness compared with equal-sized plots within larger contiguous primary forest areas (partially attributed to an influx of disturbance-tolerant species into fragments). Gascon *et al.* (1999) also studied the persistence of anurans in fragments and surrounding disturbed matrix habitat in the central Amazon over spans of up to 19 years and

found that few species were lost, overall species richness increased, and matrix-tolerant species (including many primary forest species) remained stable or increased in fragments. These investigators concluded that the Amazonian anuran community was less affected by fragmentation than other vertebrates and that many anuran species can better utilize and migrate through disturbed habitat, but they cautioned that further monitoring would be essential to discern more long-term patterns.

In an earlier study from the same area, Zimmerman and Bierregaard (1986) compared species-area relation data derived from island biogeography theory with data on ecological factors in an attempt to test which approach was a better predictor of the minimum area required to preserve the anuran fauna (39 species). They concluded that on the basis solely of species-area data, only about 500 ha would be required to preserve this fauna, but habitat heterogeneity and, especially, the distribution of breeding sites were far better predictors of the minimum area needed to ensure community survival. Without sufficient breeding sites, even larger areas would not be adequate; with abundant breeding sites and heterogeneity, an even smaller area might suffice.

Results from this study provide another long-term reference point for an exceptionally rich Amazonian herpetofauna, suggesting that some relatively small reserves could be a viable conservation strategy for these taxa in response to forest fragmentation; the high concentration and persistence of species within the small but ecologically heterogeneous (and extensively riparian) CSA is especially noteworthy in light of previous studies on Amazonian anurans.

Contrary to some initial predictions made in 1986, the EBJS herpetofauna has evidently not suffered a catastrophic decline in species richness, despite more than 20 years amidst an increasingly impacted landscape. However, although 20 years might represent a substantial time span from a human perspective, this is merely a brief instant within the far larger context of millions of years of biological evolution in the Amazonian rainforest. This small reserve might provide a model for future conservation efforts in the region, but to repeat an admonition expressed in virtually all studies on fragmented ecosystems, time and continued monitoring will be necessary to address the many questions that yet remain.

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NOTES ADDED IN PROOF

Subsequent to completion of the present manuscript, six additional species records from the EBJS have been reported; with the exception of one record (dating from 1988), all identifications were confirmed by the author from photographs (none collected). These are presented below in the same order as Appendix 1.

AMPHIBIA: Dendrobatidae: *Hyloxalus bocagei*. One adult was reported from an area 1.5 km NW of the EBJS station, in July of 2008, by Ross J. Maynard and Nathan A. Shepard.

REPTILIA: Aniliidae: *Anilius scytale*. A single juvenile was recorded on the south side of the reserve (near the Río Arajuno), 4 km SSE of the EBJS station, in July 2008 by Ross J. Maynard and Nathan A. Shepard.

Colubridae: *Atractus torquatus*. This species is tentatively included based on a photograph of one individual taken at night in primary forest (600 m south of the EBJS station, within the CSA) in July 2008, by Milton G. Orozco. Although determination was made by the author (and William W. Lamar) based on the photograph, this record would apparently represent a substantial westward range extension and the first report from Ecuador; additional material is needed for confirmation.

Colubridae: *Liophis cobella*. Reported by Bill Montgomery based on a photograph taken in July 1988 and later determined by William W. Lamar (probably from within the CSA).

Colubridae: *Oxybelis aeneus*. One adult was recorded by day from a secondary forest area 2.5 km SW of the EBJS station in August 2008, by Milton G. Orozco.

Viperidae: *Bothriopsis taeniata*. One adult was recorded by day near a stream in primary forest, 3.5 km SW of the EBJS station in March 2008, by Milton G. Orozco.

Appendix 1. List of species and distribution of records, 1986–2007.* Amphibians and reptiles recorded from the EBJS since March 1986 over five sampling periods, also including all species reported from all sources through 2007 (also see text and Tables 1, 2). Presence or absence within each sampling period (and other columns) is indicated by + or − symbols.†

Species	DFR	Presence in Sampling Period					CSA	MS
		1986 1987	1987 1988	1998 2001	2002 2003	2004 2005		
AMPHIBIANS								
Anura: Bufonidae								
Rhaebo glaberrimus	6/07	−	−	−	−	+*	+	−
Rhinella festae	3/86	+	+	+	+	+	+	+
*R. "margaritifera"**	3/86	+	+	+	+	+	+	+
R. marina	3/86	+	+	+	+	+	+	+
Anura: Centrolenidae								
Cochranella midas	8/87	+	+	+	+	+	+	+
Hyalinobatrachium munozorum	8/87	−	+	+	−	−	+	+
Anura: Dendrobatidae								
*Allobates zaparo**	3/86	+	−	+	+	+	+	+
*Amereega bilinguis**	3/86	+	+	+	+	+	+	+
A. hahneli	3/86	+	+	+	+	+	+	+
*A. parvula**	8/87	+	−	−	+	+	−	+
*Hyloxalus sauli**	11/87	−	+	−	−	+	+	+
Ranitomeya duellmani	7/87	+	+	+	−	+	+	+
R. ventrimaculata	6/86	+	+	−	−	+	+	+
Anura: Hylidae								
"Hyla" alboguttata genus *incerta sedis*	3/86	+	+	+	+	+	+	+
*Cruziohyla craspedopus**	4/98	−	−	+*	−	+*	+	−
Dendropsophus bifurcus	5/86	+	+	+	+	+	+	+
D. brevifrons	4/86	+	+	+	+	+	+	+
D. marmoratus	4/86	+	+	−	+	+	+	+
D. minutus	6/99	−	−	+	−	−	+	+
D. parviceps	3/86	+	+	+	+	+	+	+
D. rhodopeplus	5/86	+	+	+	+	+	+	+
D. sarayacuensis	8/87	+	+	+	+	+	+	+
D. triangulum	7/86	+	+	−	+	−	+	+
*Hylomantis hulli**	5/87	+	+	−	−	−	+	+
Hypsiboas boans	3/86	+	−	−	+	+	+	+
H. calcaratus	4/86	+	+	+	+	+	+	+
*H. cinerascens**	1/05	−	−	−	−	+	+	−
H. fasciatus	3/86	+	+	+	+	+	+	+
H. geographicus	8/87	+	−	−	−	−	+	+
H. lanciformis	3/86	+	+	+	+	+	+	+
H. punctatus	3/86	+	+	+	+	+	+	+
Nyctimantis rugiceps	8/87	−	+	−	−	−	+	+
*Osteocephalus cabrerai**	6/86	+	+	+	+	+	+	+
*O. deridens**	2/88	−	+	+	+	+	+	+
*O. fuscifacies**	8/87	−	+	+*	−	−	+	+
O. planiceps	6/87	+	+	+	+	+	+	+

Appendix 1. Continued.

Species	DFR	Presence in Sampling Period 1986–1987	1987–1988	1998–2001	2002–2003	2004–2005	CSA	MS
O. verruciger	8/87	+	–	+	–	+	+	+
Phrynohyas venulosa	4/86	+	+	+	+	+	+	+
*Phyllomedusa coelestis**	1/05	–	–	–	–	+	+	–
P. tarsius	8/87	–	+	–	–	+	+	–
P. tomopterna	4/86	+	+	+	+	+	+	+
P. vaillanti	3/86	+	+	+	+	+	+	+
Scinax cruentommas	5/86	+	+	+	+	+	+	+
*S. funereus**	5/90	–	–	–	+	+	+	+
S. garbei	8/87	–	+	+	+	+	+	+
S. ruber	5/86	+	+	+	+	+	+	+
Anura: Leiuperidae								
Edalorhina perezi	4/86	+	+	–	–	–	+	+
Engystomops petersi	9/87	–	+	–	+	+	+	+
Anura: Leptodactylidae								
Leptodactylus andreae	3/86	+	+	+	+	+	+	+
L. lineatus	5/86	+	–	+	+	+	+	+
L. mystaceus	5/86	+	+	–	+	+	+	+
L. pentadactylus	10/87	–	+	+	–	–	+	–
L. rhodomystax	6/03	–	–	–	+	+	+	–
L. wagneri	5/86	+	+	+	+	+	+	+
Anura: Microhylidae								
Chiasmocleis bassleri	5/86	+	–	+	+	+	+	+
Syncope antenori	3/86	+	+	+	–	–	+	+
Microhylidae *incerta sedis**	6/01	–	–	+	–	–	–	+
Anura: Ranidae								
Lithobates palmipes	6/86	+	+	+	–	–	+	+
Anura: Strabomantidae								
Isodactylus nigrovittatus	3/86	+	+	+	+	+	+	+
Oreobates quixensis	5/86	+	+	+	+	+	+	+
Pristimantis acuminatus	3/86	+	+	+	+	+	+	+
P. altamazonicus	3/86	+	+	+	+	+	+	+
*P. aureolineatus**	5/86	+	–	+	–	+	+	+
P. conspicillatus	6/86	+	–	+	+	+	+	+
P. croceoinguinis	3/86	+	+	+	+	+	+	+
P. diadematus	6/87	–	+	+	+	+	+	+
P. lacrimosus	3/86	+	+	+	–	–	+	+
P. lanthanites	3/86	+	+	+	+	+	+	+
*P. librarius**	3/86	+	+	+	–	–	+	+
P. malkini	6/87	+	+	+	+	+*	+	+
P. martiae	3/86	+	+	+	+	+	+	+
*P. ockendeni**	3/86	+	+	+	+	+	+	+
P. paululus	3/86	+	+	+	+	+	+	+
P. pseudoacuminatus	4/86	+	+	+	–	–	+	+
P. quaquaversus	6/86	+	+	+	–	–	+	+
P. variabilis	3/86	+	+	+	+	+	+	+
Pristimantis sp. I*	3/86	+	+	+	–	+	+	+
Pristimantis sp. II*	6/99	–	–	+	–	–	+	–
Strabomantis sulcatus	5/86	+	–	–	–	–	+	+

Appendix 1. Continued.

Species	DFR	Presence in Sampling Period 1986 1987	1987 1988	1998 2001	2002 2003	2004 2005	CSA	MS
Caudata: Plethodontidae								
*Bolitoglossa equatoriana**	3/86	+	+	+	+	+	+	+
*B. peruviana**	3/86	+	+	+	+	+	+	+
Gymnophiona: Caeciliidae								
Oscaecilia bassleri	6/03	–	–	–	+	–	+	–
Siphonops annulatus	6/86	+	+	+	–	+	+	+
Caeciliidae sp. *incerta sedis**	6/99	–	–	+	–	–	+	–
REPTILES								
Chelonia: Chelidae								
*Mesoclemmys gibba**	1/01	–	–	+	–	+	+	–
Platemys platycephala	7/04	–	–	–	–	+	+	–
Chelonia: Podocnemididae								
*Podocnemis unifilis**	R	–	–	–	–	–	–	–
Chelonia: Testudinidae								
Chelonoidis denticulata	12/87	–	+	–	–	–	+	–
Crocodylia: Crocodylidae								
*Caiman c. crocodilus**	R	–	–	–	–	–	+	–
Paleosuchus trigonatus	7/98	–	–	+	+	+*	+	–
Amphisbaenia: Amphisbaenidae								
Amphisbaena fuliginosa bassleri	3/06	–	–	–	–	+*	+	–
Sauria: Gekkonidae								
Gonatodes concinnatus	3/86	+	+	+	+	+	+	+
Pseudogonatodes guianensis	3/86	+	+	–	+	+	+	+
Thecadactylus solimoensis	3/86	+	+	+	+	+	+	–
Sauria: Gymnopthalmidae								
Alopoglossus angulatus	8/06	–	–	–	–	+*	–	–
Bachia t. trisanale	9/87	–	+	–	–	+	+	+
Cercosaura argulus	6/86	+	+	+	–	+	+	+
Leposoma parietale	3/86	+	+	–	+	+	+	+
Potamites strangulatus	10/05	–	–	–	–	+	+	+
Sauria: Iguanidae								
Anolis f. fuscoauratus	3/86	+	+	+	+	+	+	+
A. nitens scypheus	6/86	+	–	–	–	–	+	+
A. ortonii	7/86	+	+	+	–	+	+	+
A. punctatus boulengeri	8/87	–	+	+	+	+	+	+
A. trachyderma	3/86	+	+	+	+	+	+	+
*A. transversalis**	5/89	–	–	–	–	+	+	–
Enyalioides laticeps	3/86	+	+	+	+	+	+	+
Plica umbra ochrocollaris	3/86	+	+	+	–	+	+	+
*Polychrus liogaster**	5/89	–	–	–	+	+*	+	+
Uracentron flaviceps	1/88	–	+	–	–	–	+	–
Sauria: Scincidae								
Mabuya nigropunctata	9/87	–	+	–	–	–	+	+
Sauria: Teiidae								
Kentropyx pelviceps	3/86	+	+	+	–	+	+	+
Tupinambis teguixin	4/86	+	+	+	–	+	+	–
Serpentes: Boidae								
Boa c. constrictor	10/05	–	–	–	–	+	+	–

Appendix 1. Continued.

Species	DFR	Presence in Sampling Period 1986–1987	1987–1988	1998–2001	2002–2003	2004–2005	CSA	MS
*Corallus caninus**	?/89	–	–	–	–	+*	+	–
C. hortulanus	6/87	+	+	+	+	+	+	–
Epicrates c. cenchria	8/87	+	+	–	+	+	+	+
Serpentes: Colubridae								
Atractus elaps	11/04	–	–	–	–	+	+	–
A. gaigeae	6/03	–	–	–	+	+	+	+
A. major	3/86	+	+	+	+	+*	+	+
*A. occipitoalbus**	9/87	–	+	–	–	+	+	+
Atractus sp.*	8/87	+	+	+	–	+	+	+
*Chironius exoletus**	7/03	–	–	–	+	+	+	–
C. f. fuscus	8/87	+	–	+	–	+*	+	+
C. m. multiventris	6/87	+	+	–	–	+	+	+
C. scurrulus	11/04	–	–	–	–	+	+	+
Clelia clelia	8/87	+	–	+	–	+	+	+
Dendrophidion dendrophis	9/87	–	+	+	+	+	+	+
Dipsas catesbyi	3/86	+	+	+	+	+	+	+
D. indica ecuadorensis	3/86	+	+	+	–	+	+	+
*D. pavonina**	10/03	–	–	–	+	–	+	–
*Drepanoides anomalus**	7/87	+	–	–	–	+	+	+
*Drymobius rhombifer**	6/05	–	–	–	–	+	+	–
Drymoluber dichrous	4/86	+	–	–	–	+	+	+
Helicops angulatus	6/87	+	+	+	–	+	+	+
Imantodes cenchoa	3/86	+	+	+	+	+	+	+
I. lentiferus	3/86	+	+	+	+	+	+	+
Leptodeira a. annulata	3/86	+	+	+	+	–	+	+
Leptophis ahaetulla nigromarginatus	10/87	–	+	–	–	+	+	+
Liophis reginae semilineata	7/87	+	–	–	–	–	+	+
L. typhlus	7/03	–	–	+	–	+*	+	+
Ninia hudsoni	8/87	+	+	–	–	–	+	+
*Oxybelis fulgidus**	7/03	–	–	–	+	+*	+	+
*Oxyrhopus formosus**	9/05	–	–	–	–	+	+	+
*O. melanogenys**	6/03	–	–	–	+	+	+	+
*O. petola digitalis**	6/05	–	–	–	–	+	+	–
Pseudoboa coronata	6/00	–	–	+	–	+	+	+
Pseustes poecilonotus polylepis	8/87	–	+	–	–	+*	+	+
*P. s. sulphureus**	12/97	–	–	+*	–	–	+	–
*Siphlophis cervinus**	6/05	–	–	–	–	+	+	–
*S. compressus**	7/03	–	–	–	+	+	+	–
Spilotes p. pullatus	11/87	–	+	+	–	+	+	–
Taeniophallus brevirostris	9/06	–	–	–	–	+*	+	+
Tantilla melanocephala	11/05	–	–	–	–	+	+	–
*Umbrivaga pygmaea**	7/03	–	–	–	+	+	+	+
Xenodon r. rabdocephalus	4/06	–	–	–	–	+*	+	+
X. severus	9/87	–	+	–	+	–	+	–
Xenoxybelis argenteus	7/86	+	+	+	+	+	+	+
Serpentes: Elapidae								
Leptomicrurus narducii melanotus	7/87	+	–	–	+	+	+	+
Micrurus hemprichii ortoni	6/99	–	–	+	+	+	+	–

Appendix 1. Continued.

Species	DFR	Presence in Sampling Period 1986–1987	1987–1988	1998–2001	2002–2003	2004–2005	CSA	MS
M. lemniscatus helleri	9/87		+	+	+	+	+	+
M. ornatissimus	9/87	–	+	–	–	+	+	+
M. surinamensis	6/00	–	–	+	+	+	+	–
Serpentes: Viperidae								
Bothriopsis bilineata smaragdina	4/04	–	–	–	–	+	+	–
Bothrocophias hyoprora	9/07	–	–	–	–	+*	–	–
Bothrops atrox	3/86	+	+	+	–	+	+	+
*Lachesis m. muta**	R	–	–	–	–	–	+	–

*Asterisks by species names indicate that additional information is presented in the Results section of the text. Asterisks after + symbols for the 1998–2000 period denote species recorded earlier by other investigators (December 1997 and April 1998); these are lumped with 1998–2001 species totals in Tables 1 and 2. Asterisks after + symbols for the 2004–05 period indicate that the record came instead from 2006 or 2007; these are not included in 2004–2005 or 1998–2005 species totals in Tables 1 and 2.

†DFR = Date of first record (month/year); an "R" indicates that the species is included on the basis solely of reports by EBJS staff (dates unknown). CSA = Species presence/absence within the Central Study Area. MS = Species is represented (+) by at least one museum specimen obtained from sampling efforts reported here; see online Appendix 1.

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